# A method for a near-best sine wave from a DDS generator

**Alexia Gossa**
System programmer and electronic engineer

The present document measures the performance of conventional DDS generator and a so-called “high resolution” (HR) DDS generator using only sine wave output.

## 1. Introduction

DDS generators gradually replace conventional signal generators because of their versatility, scalability, flexibility, ease of use and low cost.

DDS generators use a ROM based value table, base clock and output DAC.
Ideally the resulting signal is near perfect with respect of the user selected settings.

DDS generators need very high speed to process samples in real time.
FPGA could provide enough power to process samples in real time and low cost FPGA are enough powerful to provide entry-level or more DDS generator.

This document is based on the FeelTech FY6800[1] generator (250SMPS 14-bit DAC).

# 2. DDS generator

The DDS generator could be separate into 4 blocks :

- Frequency and Phase control
- Load data from a ROM based value table
- DAC
- Low pass filter

**The Frequency and Phase Control**
DDS generators could use a fixed frequency clock. This document is based on fixed frequency clock.

To control the final frequency generation, 2 registers are used :

- phase accumulator
- phase adder

This document uses high resolution (64bits) phase registers to provide fine tune of very high frequency and ultra low frequency.

The maximum output frequency is always Fs/2 or the Nyquist-frequency.

**Load data from a ROM based value table**
The phase accumulator is also used to select the correct data into the table values.
A 8192-point table is used with 13-bit table offset.
To extract the correct value, the highest 13-bit of the phase accumulator are used as a table offset.
The ROM based value table stores values using 14-bit into the FPGA but 16-bit could also be used.

**DAC**
The choice of the DAC is very important and provide high or low quality.
DAC904[2] provides correct 14-bit quality.
AD9744[3] provides little higher 14-bit quality.

**Low pass filter**
It is necessary to apply a low-pass filter in order to remove any unwanted signals.
The maximum output frequency of the DDS generator must be adjusted with the cutoff frequency of the output filter to limit output artefacts.

**And so on…**
All analog processing in the signal path adds some noise and/or distortion.

# 3. High Resolution DDS generator

The HR DDS generator is based on classic DDS generator but add some additional processing to provide high quality output signal. Sine waves which are complex to produce greatly benefit from this improvement.

Only 9 to 10 instructions are necessary with only one multiplication and 3 arithmetic shifts.
Some instructions could be done in parallel to minimize negative performance impact.

Instead of using 14-bit values inside the LUT, all values are coded using 16-bit.

An additional gain stage and offset stage could be added with a single instruction (one multiplication).

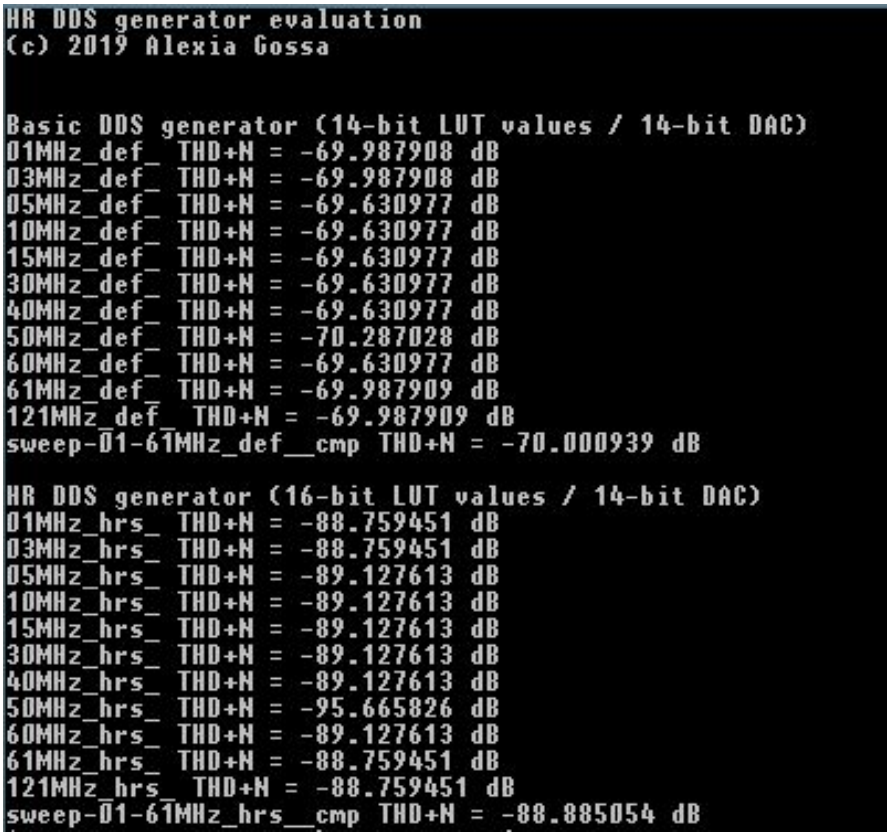
The result is a very high precision in the final 14-bit value sent to the DAC.

The HR DDS enhances all waveform types (sine, triangle, saw, exp…) except rectangle (square, pulse…).

# 4. Measurements and Results

A Basic DDS generator and a HR DDS generator are implemented in C language.
A perfect DDS generator are also implemented in C to do all measurements.
Multiple files are generated to simulate DDS generator with different settings.

**Evaluation program**




**All files are available and use this text format :**

```
dds-eval_[frequency]_[generator]_[type].wav

frequency    01MHz to 121MHz

generator    def = basic DDS generator
             hrs = HR DDS generator

type         sig = 16-bit WAVE file (level is -12dB to provide 14-bit quality)
             cmp = 32-bit WAVE file (signal compared to a perfect DDS generator)
```

dds-eval_15MHz_def__cmp.wav
    15MHz basic DDS generator minus perfect DDS generator

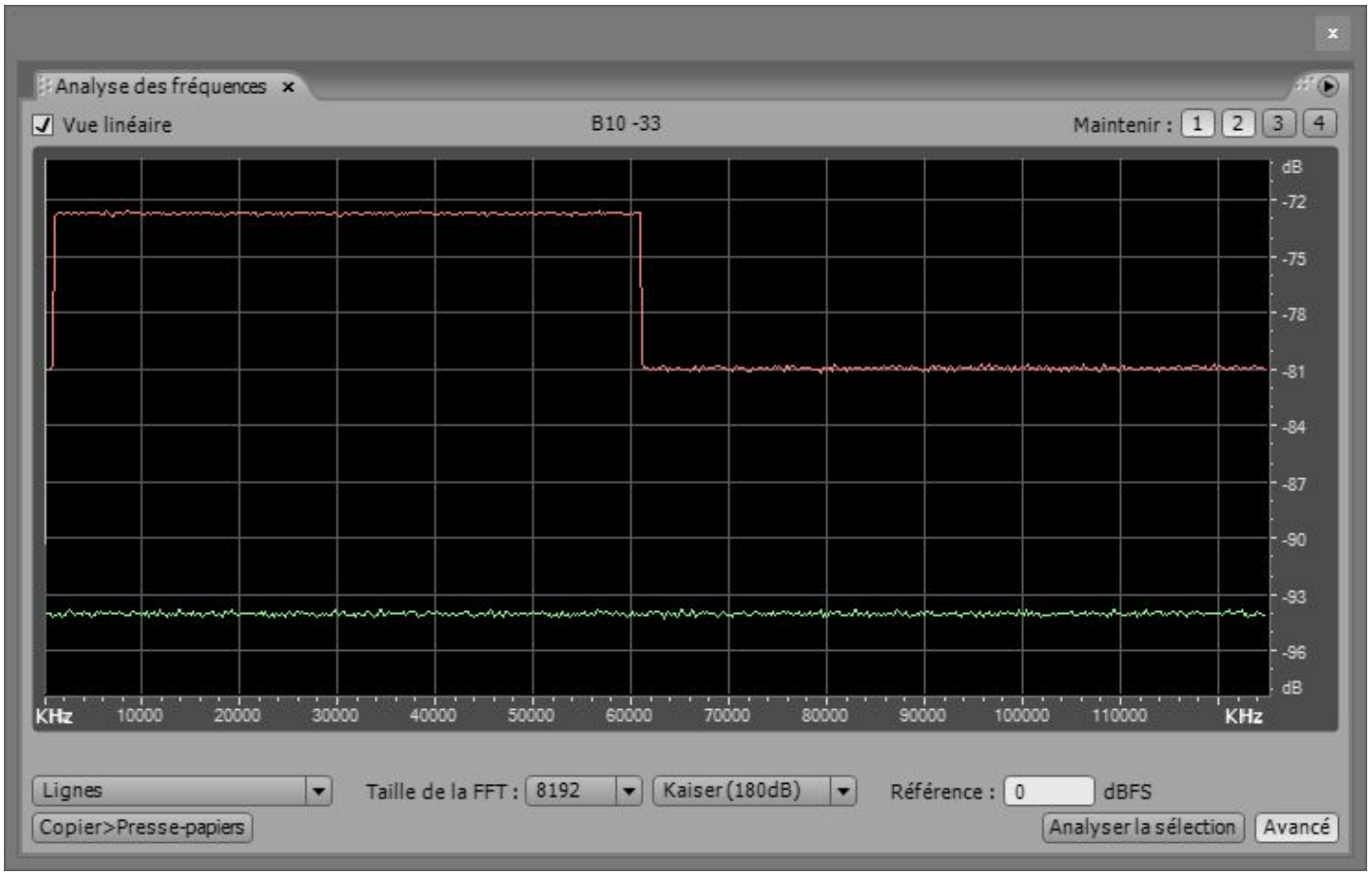
dds-eval_sweep-01-61MHz_hrs__sig.wav
    01 to 61MHz sweep of a HR DDS generator

**Measurement are done using :**

- Direct results of the DDS generator evaluation program (compiled with Visual Studio C++ 2015)[4]
- Adobe Audition 3.0[5] with 8192-point FFT analysis with Kaiser 180dB window.

**Noise floor measurement**

This measurement is done using Adobe Audition 3.0




RED curve 1MHz to 61MHz sweep of “basic DDS” minus “perfect DDS”

GREEN curve 1MHz to 61MHz sweep of “HR DDS” minus “perfect DDS”

**121MHz SPURS and THD+N measurement**

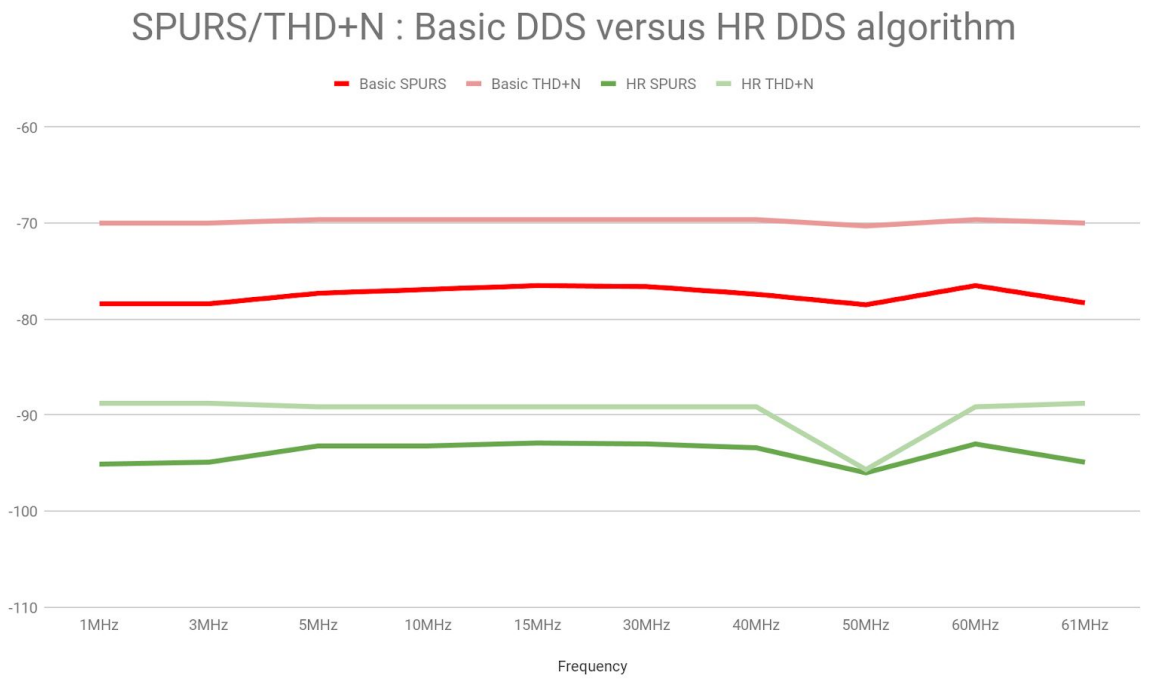
The SPURS measurement is done in frequency domain using Adobe Audition 3.0.
The THD+N measurement is provided by the evaluation program.

| | Basic DDS | HR DDS |
|---|---|---|
| SPURS | -67 dB | -83 dB |
| THD+N | -68 dB | -95 dB |

**SPURS and THD+N measurement**

We use 10 discrete frequencies to do this measurement :
1MHz, 3MHz, 5MHz, 10MHz, 15MHz, 30MHz, 40MHz, 50MHz, 60MHz, 61MHz

The SPURS measurement is done in frequency domain using Adobe Audition 3.0.
The THD+N measurement is provided by the evaluation program.




**Final results**

| | Basic DDS | HR DDS | Measurement method |
|---|---|---|---|
| THD+N | -70dB | -90dB | Multiple frequency step 1MHz to 61MHz |
| THD+N | -68dB | -95dB | Single frequency of 121MHz |
| SPURS | -77dB | -94dB | Multiple frequency step 1MHz to 61MHz |
| SPURS | -67dB | -83dB | Single frequency of 121MHz |
| Noise floor | -73dB | -94dB | 1MHz to 61MHz linear sweep |

# 5. Conclusion

This document presents measurements and results from basic DDS generator and HR DDS generator.

The proposed HR DDS generator provides a big step improvement over basic DDS generator. It allows the output signal going up to the near nyquist frequency with a low artefact level. Also the output filter could have a higher cutoff frequency (only the rejection of sampling frequency and all harmonics) than basic DDS generator.
The HR DDS generator provides these specs compared to basic DDS generator :

- Lower THD+N
- Higher SPURS
- Lower Noise floor
- Enhanced maximum output frequency
- Better linearity

Any basic DDS generator could be updated to be a HR DDS generator.

The HR DDS generator is very simple to implement and does not need any complex processing (FIR filter, convolution, butterfly…).

The HR DDS 14-bit generator outperforms Basic DDS 16-bit generators.

Using this implementation with 16-bit ROM based value table, 14-bit DAC and quality analog design, a HR DDS generator device could outperforms any higher-end “basic DDS generator” device.

# References


[1] FeelTech FY6800
http://en.feeltech.net/index.php?case=archive&act=show&aid=62

[2] Burr-Brown / Texas Instrument DAC904
https://www.ti.com/lit/ds/symlink/dac904.pdf

[3] Analog Device AD9744
https://www.analog.com/media/en/technical-documentation/data-sheets/AD9744.pdf

[4] Visual Studio 2015
https://visualstudio.microsoft.com/

[5] Adobe Audition 3.0
https://www.adobe.com/fr/products/audition.html
https://help.adobe.com/archive/fr_FR/audition/3/audition_3_help.pdf